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Pricing as a demand management tool for record communications

DiMaggio, Kathryn A.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

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PRICING AS A DEMAND MANAGEMENT
TOOL FOR RECORD COMMUNICATIONS

by

Kathryn A. DiMaggio

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The Naval Telecommunications System (NTS), by achieving connectivity through various networks, provides record ommunications within the Navy. This service is provided to a wide variety of users with different requirements.

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This thesis looks at how prices could be used as a demand management tool, to ensure messages reach their destination s prescribed by the originator. It also proposes a cost estimation model which, if implemented, could provide justifiable cost ased prices and serve as a basis for demand based and congestion based prices.

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Pricing as a Demand Management Tool for Record Communications

by

Kathryn A. DiMaggio
Lieutenant Commander, United States Navy
B.S., University of Wisconsin-Madison, 1978

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requirements for the degree of

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ABSTRACT

The Naval Telecommunications System (NTS), by achieving connectivity through various networks, provides record communications within the Navy. This service is provided to a wide variety of users with different requirements.

Currently, this service is provided without cost to the user. Because the service is free, there is no overt incentive to economize on its use. This may be one reason for an increase in message volume in past years. As a result of the overwhelming demand for record communications, the Naval Telecommunication System has experienced periods of delay in delivering messages to their destination.

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A. PURPOSE

The Naval Telecommunications System (NTS), by achieving connectivity through various networks, provides record communications within the Navy. The Naval Telecommunications System provides service to a wide variety of users, with different requirements.

Currently, this service is provided without cost to the user. Because the service is free, there is no overt incentive to economize on its use. This may be one reason for an increase in message volume in past years. As a result of the overwhelming demand for record communications, the Naval Telecommunication System has experienced periods of delay in delivering messages to their destination.

Charging a command for use of the NTS may be an effective tool to manage the demand for record communications.

B. OBJECTIVES AND RESEARCH QUESTIONS

The object of this thesis is to examine alternative pricing mechanisms to manage *demand* and increase the efficiency of the NTS. Pricing will give users incentives to economize on the number, destination, length, and precedence of messages sent. This would allow the managers of the NTS to concentrate on primary missions, as opposed to reactive measures during periods of high demand.

To meet this objective the following questions were explored:

- How is demand currently managed for record communications?
- What are the possible pricing mechanisms?
- What effect would each pricing mechanism have on the demand for record communications?
- What costs are associated with record communications?

C. SCOPE

This thesis is an analysis of what pricing mechanisms could be used to effectively and efficiently manage the demand for record communications. Additionally, a cost estimation model for collecting and accounting for costs of record communications is proposed to provide the data necessary to implement the appropriate pricing mechanism(s). This thesis will help establish the framework for pricing as a demand management tool. Ascertaining a precise dollar price would require modeling the complexities of the NTS system and collecting a vast amount of cost and demand data, which exceeds the scope of this thesis.

D. ORGANIZATION OF STUDY

This chapter provided an introduction to demand management for record communications. Chapter Two looks at economic concepts and theory. Chapter Three applies the economic concepts and theory to record communications. It also analyzes the effectiveness of current demand procedures. Chapter Four summarizes pricing mechanisms that are appropriate when demand exceeds supply. Chapter Five discusses a cost estimation framework and model for record communications used in collecting data necessary to implement pricing mechanisms. The last chapter provides the conclusions of this thesis and suggests areas for further study.

II. DEMAND MANAGEMENT: ECONOMIC CONCEPTS

A. INTRODUCTION

Demand management is the practice of equating expected *demand* and expected *supply*, without causing a surplus or excess demand. It is the application of microeconomics, the study of scarce resource allocations. The capacity for record communications is a scarce resource, as users want to send more messages than the communications system can deliver within the designated speed of service. Thus, management of record communications can be viewed from the framework of microeconomics.

This chapter establishes the economic framework and defines economic concepts with respect to demand management. This chapter also summarizes how *demand* is managed in the private sector.

B. CONCEPTS AND THEORY

1. Demand

Demand is the quantity of a good or service that consumers are willing and able to purchase at specified prices. It reflects the value or benefit of the good or service to the consumer. As price changes, the quantity the consumer is willing and able to purchase also changes. Similarly, value or benefit changes. Demand may be represented in a graph, with axes of quantity, and price or dollars per unit (see Figure 1). *Demand*, or the demand curve, represents the additional value or benefit gained when the user receives more unit. This is referred to as the *marginal value* or *marginal benefit*.

The demand for a good or service is assumed to be based on various factors such as price of the good, taste, and income. These factors are the determinants of demand. *Demand* may change if any of the determinants change. There are two types of changes: movements along the demand curve and shifts in the demand curve.

If only the price of the good changes, the quantity demanded by the consumer will also change. This is represented by a movement along the demand curve. In Figure 1, a change in price from P to P' will cause a movement along demand D; quantity demanded changes from Q to Q'. The law of demand states that "consumers are willing and able to buy more of a good the lower the price of a good, when all other variables are held constant." [Ref. 1: p. 13]

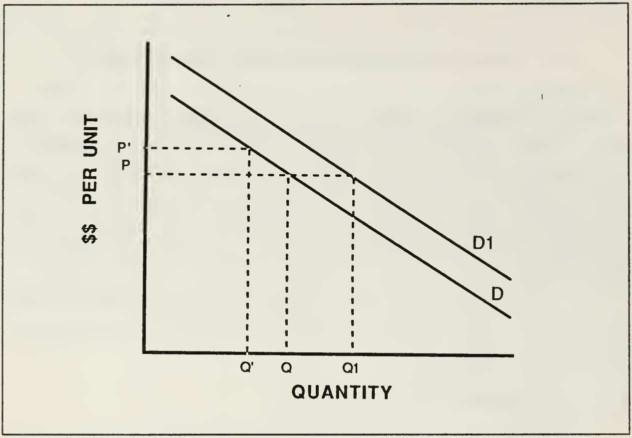

Figure 1. Demand

A change of any determinant except price, shifts the demand to a new relationship between quantity and price. A shift in demand, represented by *D* to *D1* in Figure 1 on page 4, changes the quantity demanded at price *P* from *Q* to *Q1*. [Ref. 2: p. 18-27]

2. Supply

Supply is the amount of a good or service that a group of suppliers or firms would be willing to offer at given prices. It reflects the cost (actual and opportunity) to supply that good or service. Like demand, *supply* may be represented in a graph (see Figure 2 on page 5). It represents the *marginal cost*, the additional cost to produce one more unit.

The supply for a good or service is assumed to be based on various factors such as price, technology, and price of inputs. *Supply* changes if any of the factors of supply change. There are two types of changes in *supply*: movement along the supply curve and shifts in the supply curve.

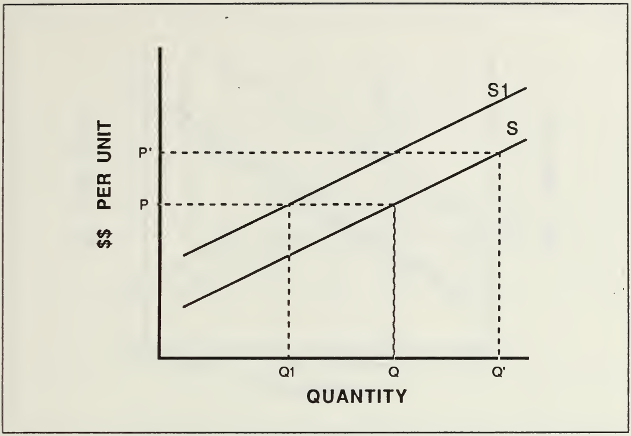

Figure 2. Supply

If only the price of the good changes, the quantity supplied will also change. This is represented by a movement along the supply curve. As price changes from *P* to *P'* on the supply curve *S* (Figure 2 on page 5), the quantity supplied changes from *Q* to *Q'*. The law of supply states, "the higher the price of a good or service the more will be offered for sale." [Ref. 1: p. 58]

A change in any factor except price, shifts supply to a new relationship between quantity and price. A shift in supply, represented by *S* to *S'* in Figure 2, may be attributable to a change in the price of inputs or technology. [Ref. 2: p. 18-29]

3. Market Equilibrium

Market equilibrium exists when the quantity demanded equals the quantity supplied. At price *Pe*, in Figure 3 on page 6, consumers demand quantity *Qe*, and suppliers will supply quantity *Qe*. Excess demand or surplus exists when current price is not at the equilibrium price. [Ref. 2: p. 36]

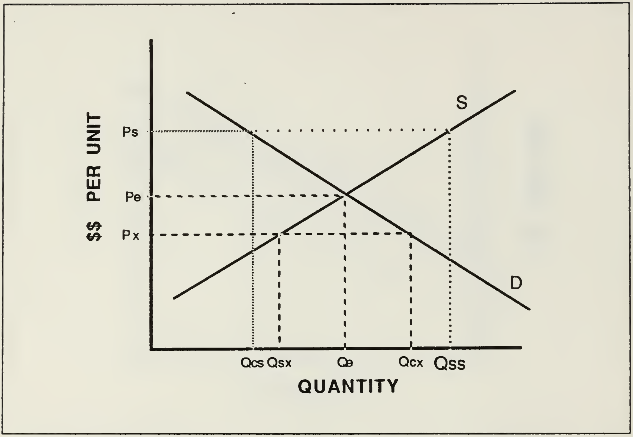

Figure 3. Market Equilibrium

If the current price is below equilibrium price, there is excess demand; consumers are willing and able to purchase more than suppliers are willing to supply. At price *Px*, in Figure 3 on page 6, consumers demand quantity *Qcx*, but suppliers produce only quantity *Qsx*. When the current price is above equilibrium price, surplus exists; consumers are unwilling or unable to purchase the amount suppliers produce. At price *Ps*, in Figure 3, consumers demand only quantity *Qcs*, and suppliers produce quantity *Qss*. [Ref. 2: p. 36]

Barring any external forces, such as a limited supply, the market will automatically converge to the equilibrium price. This requires that price and quantity be perfectly variable to the shifts in supply or demand. If price and quantity cannot vary, excess demand and/or a surplus can be expected. For instance, in Figure 4 on page 7, if the capacity of a system was fixed at *Qc* (quantity is not perfectly variable) and demand shifted from *D* to *D1*, equilibrium price would increase to capacity price, *Pc*. At this price, the quantity demanded and quantity supplied are both equal to the system

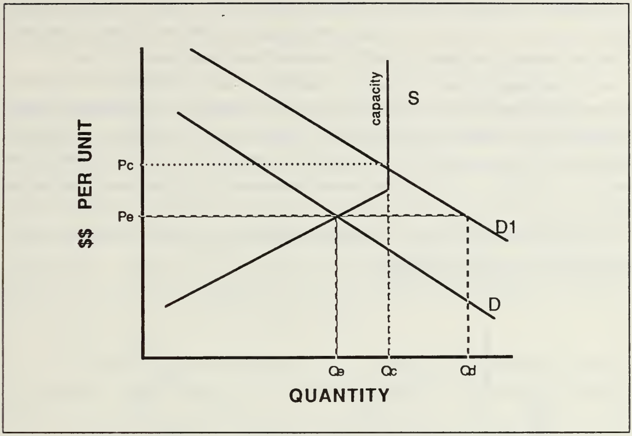

Figure 4.   Expected Excess Demand

capacity Qc. However, if the price was always set at price Pe (price is not perfectly variable), and demand shifted to $D1$, an excess demand of Qd - Qc exists.

4. Efficiency

Efficiency implies that the maximum benefit for both consumers and suppliers is derived. Efficiency can be accomplished in two ways: maximizing the benefits from a given amount of resources or by minimizing the resources used for a given amount of benefits [Ref. 1: p.13]. As long as marginal benefits exceed marginal costs, the consumer and/or the supplier is getting more benefit for less cost. This continues until marginal cost equals marginal benefit; after that point marginal cost exceeds marginal benefit and the consumer and/or supplier is paying more than the benefits received. Thus, efficiency is maximized when marginal benefits are equal to marginal costs. [Ref. 2: p. 53, 107]

If *demand* and *supply* accurately measure all benefits and costs, efficiency is maximized at market equilibrium. However, if price and quantity cannot automatically adjust, creating surplus or excess demand, efficiency will not be maximized at equilibrium. In situations of excess demand, the consumers with the highest marginal benefits must be served first to maximize efficiency. In situations of surplus, suppliers using the cheapest resources (minimizing costs) will lead to efficiency.

Additionally, if all costs are not captured or perceived in *supply* or *demand*, market equilibrium will not result in efficiency. For example, if the administrative costs for running government programs are not perceived by the consumer, *supply* will indicate a lower marginal cost. In Figure 5, the observance of supply ***Si***, results in an incorrect equilibrium; price at, ***Pi***, and quantity demanded, ***Qi***. The "true" supply is ***St***, which means the quantity demanded, ***Qi*** is produced at a marginal cost of ***Cmc***, which is in excess of marginal benefit. To maximize efficiency, only the quantity, ***Qe*** should be produced and sold at the price ***Pe***.

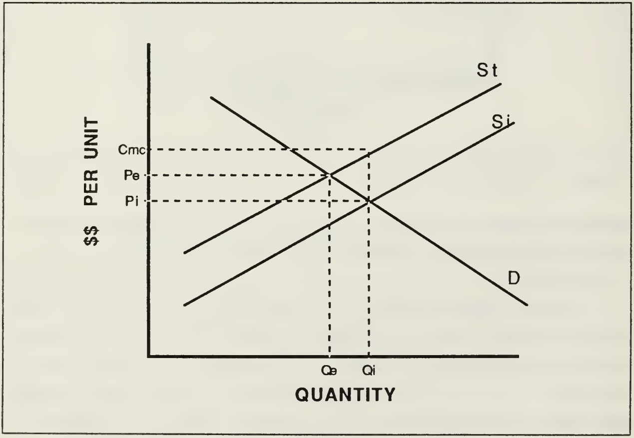

Figure 5. **Inefficiency at Equilibrium**

5. Demand Management Practices

Demand management is the practice of equating *demand* and *supply*. It is used in situations where the market cannot automatically adjust to the equilibrium price (i.e., price or quantity constraint) or when consumers do not perceive the appropriate demand or supply (i.e., impulse buying or government discounts).

Prices are used in the private sector to manage the demand for a good or service. In situations of excess demand and an inability to increase the supply, or when true cost is not perceived, pricing mechanisms targeted at *access* or *use* are employed. Typically, targeting *access* effects *use* and vice versa. For instance, restricting access produces fewer users and *use* may drop. Also, if the marginal cost of *using* the good or service is low (high), consumers may desire more (less) access.

a. Access

Limiting access to a good or service may be accomplished by charging users a hook-up fee. Admission into a museum for an unspecified amount of time and a monthly service charge for a telephone connection which is paid regardless of level of use are examples of a hook-up fee pricing mechanism.

b. Use

Several pricing mechanisms are used to manage the *use* of a good or service. The appropriate mechanism(s) is based on the predictability and duration of excess demand.

When demand is consistently greater than supply, average cost or marginal cost pricing is used. Public utility pricing is based on these mechanisms. If demand is greater than supply in predictable periods, peak load pricing is appropriate. Long distance telephone rates, based on time of day, day of week, are an example of peak load pricing. Finally, when excess demand is random, priority pricing is most efficient. Price discounts for interruptible utility service is an example of priority pricing. Pricing mechanisms are discussed in Chapter Four.

III. DEMAND MANAGEMENT FOR RECORD COMMUNICATIONS

A. INTRODUCTION

The capacity for record communications is a scarce resource, as users want to send more messages than the communications system can deliver within the designated speed of service. Thus, management of record communications can be viewed from the framework of microeconomics.

This chapter applies the economic concepts and theory to record communications. This chapter also examines how *demand* is currently managed, and the effectiveness of the management practices.

B. RECORD COMMUNICATIONS APPLICATION

1. Demand

The demand for record communications could be viewed as the number of messages users desire to send. Any individual authorized to draft, release and/or process electronically transmitted messages is a user. The user decides how to complete each element of the message (see Figure 6) prior to requesting its delivery. [Ref. 3]

- Precedence
- Addresses
- Security classification
- Text
- Special handling requirements
- Administrative designation

Figure 6. Elements of a Message

Some determinants of the demand for record communications are listed in Figure 7 on page 11 [Ref. 4: p. 86]. The demand for record communications will change if there is a change in any of the determinants other than price. This change in demand would be represented by a shift in the demand curve. Currently, the service is priced at zero. Therefore, users will demand service as long as they receive any positive benefit from using record communications.

- Average price of a Navy message
- Quality of service
- Speed of service
- Security
- Reliability
- Business connection with organization called
- Mission requirements
- Defense condition (posture)
- Relative echelon/chain-of-command.

Figure 7. Proposed Determinants of Navy Demand for Communications

2. Supply

The Naval Telecommunications System is the "firm" that supplies the service of record communications. It is a complex of equipment and facilities that provides a telecommunications network for the operation, command and control, and administration of the Navy. [Ref. 5]

The service is accomplished by accepting a message from the user, transmitting it to the servicing telecommunications center(s), and delivering it to the appropriate addresses. Each of these steps may be viewed as a queuing situation. The characteristics of queuing situations are listed in Figure 8 on page 12 [Ref. 6: p. 566]. Messages arrive randomly at a telecommunications center in a physical (i.e., paper) or electrical format. Processing time, at this step, depends on the length and format of the message. In the other steps, transmission and delivery, processing time is uncertain and arrival random for similar reasons. The fixed capacity of the NTS at each step and the random arrival times of messages may cause congestion. Extensive congestion leads to a delay of message delivery. Additionally, because the NTS uses a priority queuing system (i.e., higher precedence messages are processed first, delaying lower precedence messages), the precedence level assigned further impacts delay of delivery.

3. Market Equilibrium

Market equilibrium for record communications may be considered the point at which the number of messages sent (demand) equals the ability of the NTS to deliver those messages as requested (supply) without underutilization. The speed of service

- Arrivals require service.
- Demand for service (timing and quantity) is uncertain.
- Service facilities, or servicers, perform the service.
- Duration of service is uncertain.
- Behavior of arrivals, as they arrive and/or wait, is uncertain.

Figure 8. Characteristics of a Queue Situation

requested (precedence level) is the most difficult to meet because the NTS is a congestion-based system. Thus, the amount of congestion dictates market equilibrium.

Factors contributing to congestion and delay are:

- Number of messages (including number of addees);
- Length of message;
- Precedence level assigned;
- Arrival rate at telecommunications centers (volume within a time period); and
- Speed of processing.

To illustrate the effect of these factors, the queue situation of a message awaiting transmission is used. Assume the speed of transmission is ten characters per second. One message of 60 characters and two messages of 30 characters would take six seconds to be transmitted. Suppose Message A is in line when Message B arrives. Message B is 40 characters long and has a higher precedence, so it goes to the head of the line. Message A must now wait an additional four seconds before transmission because of the precedence level. The rate in which messages arrive at the message center has a dramatic effect on delay. If twenty messages of 100 characters each with the same precedence arrive at the message center simultaneously, they would be transmitted one right after the other. The first message, assuming no other messages are in line, would take ten seconds whereas the last would be delayed 200 seconds. The average delay for the 20 messages is 105 seconds. If the same messages arrived at the message center in intervals of ten seconds, each would only take ten seconds (assuming no other messages in line) for transmission, because each message was the first in line. The average delay for the 20 messages would be ten seconds.

If any of these factors: number, length, precedence, arrival rate, or speed of processing; were changed, the amount of congestion and expected delay would change.

Excess demand exists when the number of messages sent, are not delivered in the time requested. Excess demand can be identified by a backlog of messages (i.e., paper format) awaiting entry into the NTS, high circuit utilization (mean arrival rate divided by mean service rate)[1] , and a backlog in reproduction and local distribution. A surplus exists when the capability to send, exceeds the requested service. Surplus can be identified by idle telecommunication centers, low utilization, and idle circuits.

Excess demand and surplus may be apparent to the suppliers of record communications by activity level alone. The users, however, may be unaware of excess demand or surplus caused by congestion. Users deliver their messages to a message center and leave. They may be totally unaware of the volume, length, or precedence of messages, other than their own, that are arriving at the message center. This gives reason to believe, that users do not perceive the actual marginal cost (both operation and congestion) of providing record communications or *supply*.

Assuming equilibrium exists where messages are delivered in the time requested with no under utilization, NTS would not normally be in equilibrium because price and quantity cannot automatically adjust to equilibrium. In Figure 9 on page 14, demand for record communications is assumed to be ***D*** and supply is assumed to be ***S***. To be in equilibrium quantity demanded would be *Qe*. If price is set at zero, excess demand of *Q′* - *Qe* exists. Excess demand results in delay of messages. If demand shifts, to ***D1***, due to the defense posture, or another period of peak demand, the over all effect is further delay in messages.

Because the price for sending a message is zero, and quantity cannot always be adjusted, excess demand can be expected.

4. Efficiency

Efficiency implies that the maximum benefit for both users and suppliers is derived. Thus to maximize efficiency, messages must be delivered in order of highest to lowest marginal benefits. Furthermore, service should not be requested for messages where the total marginal cost exceeds the marginal benefit. To ensure this, both the

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1 On a per message basis, mean arrival rate is the number of messages times the average number of characters. Utilization computed on System Reporting Processing Report (SRPA) reports uses a 24 hour period. It may be calculated by first computing the mean arrival rate of characters per second [(number of messages per 24 hours) times (the average length) divided by 86400] and then dividing by mean service rate [characters per second].

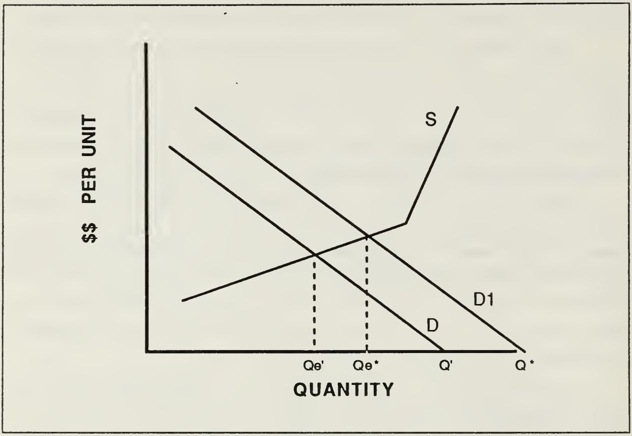

Figure 9. **Demand for Record Communications**

operating costs of providing record communications and the effect of congestion must be recognized by the user. Maximizing efficiency for record communications is difficult because price and quantity cannot automatically adjust to equilibrium, and all costs (e.g., congestion) may not be perceived by the user. This requires use of demand management.

5. Demand Management Practices

Demand management practices are necessary to maximize efficiency in situations where demand and supply will not normally be in equilibrium and/or when all benefits or costs are not captured or perceived. Both situations are evident in record communications. Two areas that demand management for record communications must address are: congestion (because users do not perceive the cost of congestion) and marginal benefit received from messages.

In dealing with congestion, demand management practices for record communication could be focused on either *access* or *use*. Due to the need of universal access for record communications, *access* is dismissed as a demand management alternative.[2]

As discussed above, factors contributing to congestion and delay are:

- Number of messages (including number of addees);
- Length of message;
- Precedence level assigned;
- Rate messages arrive at telecommunications centers (volume within a time period); and
- Speed of processing.

Speed of processing is a factor of supply. The remaining factors are determined by the user and are targets for demand management.

Currently, messages are not identified in terms of marginal value. However, they are identified by how fast they must be delivered (i.e., precedence level).

C. CURRENT DEMAND MANAGEMENT PROCEDURES

Administrative procedures are used to manage the demand for record communications. The primary procedures are published in the Navy Telecommunications Users Manual (NTP 3) and Chief of Naval Operations' directives.[3]

1. The Navy Telecommunications Users Manual (NTP 3)

NTP 3 [Ref. 3] targets three factors that contribute to congestion and delay: length, precedence, and volume. Guidance is given regarding brevity of text and precedence assignment. Volume is addressed by requiring personnel with "release authority" to determine if the message qualifies (qualification is based on other directives) for electrical transmission or whether it should be sent via the postal system. Additionally, NTP 3 provides for forced management of demand when emergency situations require reduction of telecommunications to a particular area. This situation is referred to as Minimize. [Ref. 3]

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[2] *Access* as a demand management tool, applied to particular communications systems, is the thesis of Psillas [Ref. 7].

[3] Administrative Intercept, broadcast preparation and similar programs do not impact the number of messages users send. They attempt to equate demand and supply without influencing the user's demand. This discussion is focused at effecting the user's behavior.

2. Chief of Naval Operations' Directives

Beginning in April 1985, directives requiring the reduction of message volume being electronically transmitted were issued. The directives include:

- NAVOP 142/85 *Mailed Message Pilot Program*
- NAVOP 069/86 *Navy Mailed Message Program*
- NAVOP 116/86 *Communications Discipline*
- OPNAVNOTE 2300 of 11 December 1986, *Communications Discipline*
- NAVOP 013/89 *Communications Discipline*

These directives emphasize a need for message volume reduction, provide an alternative to record communication (e.g., Navy Mailed Message Program (NAVGRAM)), and require commands to establish programs to meet volume restrictions [Refs. 8, 9 , 10 & 11]. The latest directive, [Ref. 12] states:

> The 1989 goal is a five percent reduction in message traffic. Success in communications discipline can be achieved, as has been proven in numerous fleet exercises, through application of established principles and procedures. Proper assignment of precedence, intelligent determination of addees, generous use of abbreviations in consideration of brevity, identification of the message as admin, and the decision to send it as a NAVGRAM when appropriated are some of the basics that when uniformly applied ensure efficient use of communications circuits.

D. EFFECTIVENESS OF DEMAND MANAGEMENT PROCEDURES

Two measures of effectiveness of current demand management procedures are:

- Does demand management target congestion?
- Is the market in equilibrium?

1. Demand Management Targets

Demand management procedures for record communications should be focused on congestion and delay. Users control four factors contributing to delay:

- Number of messages (including number of addees);
- Precedence assignment;
- Message length; and
- Arrival rate of messages at a telecommunications center (volume within a time period).

As indicated by NAVOP 013/89, current administrative procedures target the number of messages, precedence assignment and message length. Data indicates that administrative policies to control message volume have achieved a degree of success. The total number of messages accounted for in the Naval Communications Processing and Routing System (NAVCOMPARS) and the Local Digital Message Exchange (LDMX) are shown in Figure 10. It suggests message growth began tapering off in 1985, which coincides with the CNO directives. Historical data pertaining to precedence assignment and message length was not found.

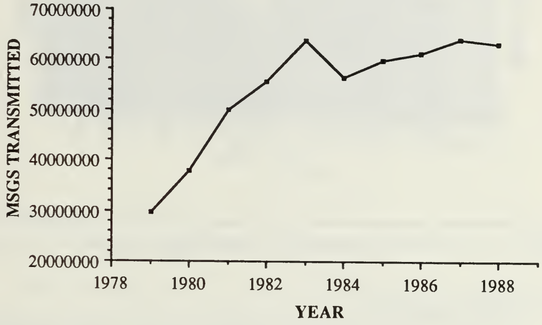

Figure 10. Volume of Transmitted Messages (Annual)

Volume of messages in specific time periods, such as time of the day or day of the week, has not been a target in recent demand management procedures. Telecommunications centers experience an increase in outgoing message traffic coincident with the end of the work week, end of the month, and end of the work day [Ref. 13]. The backlog of message volume by hour for a Fleet Broadcast channel, and the day of the week totals for an Automatic Digital Information Network (AUTODIN) channel, both compiled from [Ref. 14] reveal similar indications. See Figure 11 on page 18 and Figure 12 on page 19. Additionally, message volume may randomly increase as world situations change [Ref. 13].

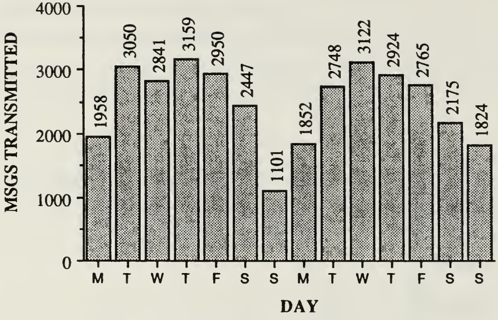

Figure 11. Transmitted Messages (Day of the Week)

2. Market Equilibrium

The supply and demand for record communications is not always in equilibrium. A snapshot comparison of messages delivered over a ten day period over three different circuits, a Fleet Broadcast (FBC) channel, a Common User Digital Information Exchange (CUDIX) special subscriber, and an AUTODIN channel, illustrates this point [Ref. 14]. Displayed in Table 1 on page 22, Table 2 on page 23, and Table 3 on page 24, is the utilization rate, average length and number of messages (total and by precedence) and the average delivery time by precedence. Table 1 breaks the number of messages by precedence into those that met and exceeded speed of service objectives. The tables illustrate four important points: average length and number of messages effect the utilization rate, the utilization rate effects the average delivery time, utilization rate differs among transmission medium and/or systems, and speed of service objectives are not always met.

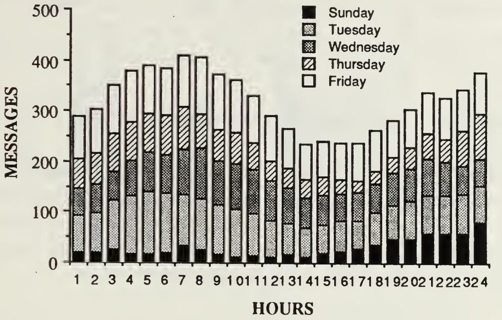

Figure 12. Message Backlog by Hour

First, the average length and total number of messages effect the utilization rate. For instance, in Table 1 the first Monday reported has an utilization rate of 88% with 373 messages of an average 2044 characters in length. The second Monday, utilization increased six percent, primarily influenced by the 105 additional characters in length. Secondly, the average delivery time increases as utilization rate increases. Table 1 displays utilization rates of 77-107%. The average delivery time for routine messages varies from one and a half hours to over thirteen hours. Table 2 displays utilization rates of 20-44% with an average delivery time for routine message of one to 17 minutes. Thirdly, the tables also show a range of utilization rates for each transmission mode (77-107% for FBC, 20-45% for AUTODIN, and 0-1% for CUDIX). This infers that equilibrium for record communications is specific to transmission medium and/or system. Finally, Table 1, illustrates that the speed of service objective is not consistently met. Figure 13 on page 21, the number of messages that met and exceeded the speed of service for the immediate messages on the Fleet Broadcast channel, (from Table 1) highlights this point.

The speed of delivery for the tables only reflects the elapsed time from receipt at the NAVCOMPARS located at Norfolk, VA, to delivery of the message at its next destination. This is the speed of service normally reviewed. However, as discussed below, this may give an inaccurate picture of the actual speed of service messages experience.

E. ASSESSMENT OF DEMAND MANAGEMENT PROCEDURES

1. Data

The data available to determine if the NTS is meeting the speed of service objectives is incomplete and misleading. Although available, the total elapsed time from the writer's telecommunications center to the reader's telecommunications center is not normally documented. Additionally, this elapsed time does not consider the potential delay in reproduction and routing to the receiving command.

a. Entry into the NTS

The first possible point of delay, is when a message is accepted from the user. Time of receipt from the user is time-stamped, and the time it entered into the NTS (e.g., NAVCOMPARS) is recorded by the computers. The difference between arrival at the message center and entry into the system, which may be significant, is not normally recorded.

b. Transmission

The delay or time difference between entry and exit in the NAVCOMPARS, provided the most concrete information regarding speed of delivery. This information, however, was somewhat misleading because it is reported message delivery speed as an *average* of all messages' delay. Average time of delay, as revealed in Table 1, distorts the delivery speed of individual messages, giving the impression that speed of service objectives are met. (NAVCOMPARS reports do not readily show the number of messages that exceeded the speed of service objectives.) Comparing the average speed of delivery for immediate messages, provided in Table 1, to the number of messages that met and that exceeded the speed of service objective (in Table 1 or Figure 13 on page 21) reinforces this point.

The utilization rate reported in the SRPA reports is based on a 24-hour period, thus not giving the proper indication of congestion at a given period of time. An indication of congestion is given in message backlog (see Figure 12 on page 19).

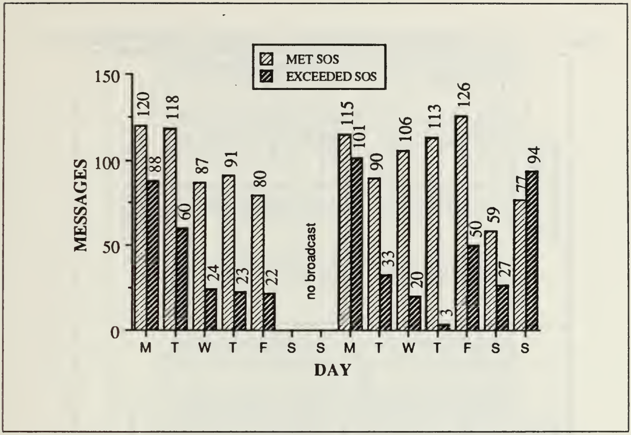

Figure 13. Messages Meeting and Exceeding Speed of Service Objective

However, only the number of messages, not number and length is reported in message backlog.

c. Delivery

No record of the last step, delivery to the user, was found. The last recorded time is a message's arrival at the servicing telecommunication center. The time it takes for reproduction and distribution is not recorded.

2. Demand Management for Record Communications

Demand management is necessary to maximize the efficiency of the NTS, because price and quantity cannot readily adjust to equilibrium, and because users may not perceive the actual marginal cost of record communications. Current administrative procedures are not sufficient to combat message delay. Although it appears by looking at the average handling time that messages are delivered within the speed of service objectives, Table 1 on page 22 and Figure 13 reflect that 31.5% of the messages in the immediate precedence level over a ten day period on a FBC channel did not meet speed of service objectives.

Table 1. FLEET BROADCAST CHANNEL: MESSAGE SUMMARY

Day	Utilization Rate	Average Length	Total Messages	Speed of Service (met/exceeded*)				Average Delay (hours:minutes)			
				Y/F	*O*	*P*	*R*	*Y/F*	*O*	*P*	*R*
MON	88%	2044	373	15/00	120/88	123/02	24/01	:03	:20	1:30	13:51
TUE	102%	1992	445	13/00	118/60	170/23	57/04	:02	:17	1:38	9:24
WED	98%	2186	390	12/00	87/24	171/19	58/19	:03	:13	1:37	5:29
THU	107%	2677	346	6/00	91/23	114/30	76/06	:02	:15	:46	4:31
FRI	100%	2348	371	4/00	80/22	157/26	59/23	:04	:11	1:16	2:17
SAT	Did not key broadcast										
SUN	Did not key broadcast										
MON	94%	2149	381	8/00	115/101	140/02	15/00	:03	:24	1:19	1:42
TUE	106%	2231	411	15/00	90/33	201/15	52/05	:02	:21	2:21	6:00
WED	104%	2097	429	4/01	106/20	188/19	84/07	:06	:14	1:04	8:34
THU	98%	2191	387	7/00	113/03	175/06	81/02	:03	:20	:27	1:31
FRI	102%	2507	352	2/00	126/50	130/11	30/3	:02	:15	1:42	4:02
SAT	77%	2345	284	0/01	59/27	115/03	71/08	:12	:19	1:19	8:24
SUN	99%	2659	324	2/01	77/94	123/04	23/01	3:02	:43	3:57	6:58

*Exceeded times (limited by report):
Y/F $\geq$ 10 minutes
O $\geq$ 30 minutes
P $\geq$ 150 minutes
R $\geq$ 330 minutes

Table 2. AUTODIN CHANNEL: MESSAGE SUMMARY

Day	Utilization Rate	Average Length	Total Messages	Number of Messages				Average Delay (hours:minutes)			
				Y/F	*O*	*P*	*R*	*Y/F*	*O*	*P*	*R*
MON	25%	1685	1958	6	441	797	714	:01	:01	:01	:01
TUE	45%	1917	3050	1	455	1218	1376	:00	:01	:01	:01
WED	38%	1757	2841	4	377	1133	1327	:01	:01	:01	:01
THU	43%	1765	3159	9	375	1288	1487	:01	:01	:01	:01
FRI	39%	1713	2950	3	349	1211	1387	:01	:01	:01	:01
SAT	41%	2210	2447	10	378	928	1131	:01	:04	:06	:17
SUN	20%	2401	1101	8	215	503	375	:00	:03	1:12	:01
MON	24%	1730	1852	2	293	750	807	:01	:00	:01	:01
TUE	41%	1946	2748	3	339	1209	1197	:01	:01	:01	:01
WED	44%	1835	3122	6	354	1162	1600	:00	:01	:01	:01
THU	40%	1811	2924	2	365	1150	1407	:01	:01	:01	:01
FRI	40%	1912	2765		272	1121	1372		:01	:01	:01
SAT	34%	2069	2175	3	298	988	886	:00	:03	:05	:03
SUN	38%	2743	1824	3	244	1070	507	:00	:16	:07	:12

Table 3. CUDIX: MESSAGE SUMMARY

Day	Utilization Rate	Average Length	Total Messages	Number of Messages				Average Delay (hours:minutes)			
				Y/F	*O*	*P*	*R*	*Y/F*	*O*	*P*	*R*
MON	1%	3316	94		27	37	30		:02	:03	:04
TUE	1%	2725	151	7	48	54	42	:01	:02	:03	:15
WED	1%	3149	137	1	47	51	38	:01	:03	:03	:04
THU	1%	3240	126	0	39	58	29		:03	:02	:14
FRI	1%	3645	106		24	43	39		:04	:03	:06
SAT	0%	2328	29	0	11	12	6		:03	:02	:10
SUN											
MON	0%	2969	66	1	11	36	18	:01	:02	:02	:03
TUE	1%	3806	119	4	17	47	51	:01	:03	:20	:22
WED	0%	3071	99	1	16	51	31	:00	:03	:05	1:02
THU	1%	2637	109	2	25	52	30	:01	:01	:05	:11
FRI	0%	2691	89		10	52	27		:01	:04	:06
SAT	0%	2669	51		10	30	11		:04	:03	:33
SUN	0%	4027	64		9	28	27		:03	:04	:03

IV. PRICING MECHANISMS

A. INTRODUCTION

Pricing is the primary tool for demand management in the private sector. Various pricing mechanisms are employed based on the relationship between *supply* and *demand.* This chapter describes the pricing mechanisms used in situations where *demand* exceeds *supply.* It discusses how each pricing mechanism could be applied to record communications and the expected results.

B. SPECIFIC PRICING MECHANISMS

The appropriated pricing mechanism(s) is based on the predictability and duration of excess demand. Cost-based pricing mechanisms are used to equate the expected demand and expected supply. Demand-based pricing mechanisms are used in situations where demand fluctuates. Congested systems may also apply a congestion-based pricing mechanism.

1. Cost Based Pricing Mechanisms

a. Cost Definitions

Cost based pricing mechanisms are directly related to the actual cost of the good or service. Several costs enter into the calculation of a cost-based price: fixed costs, variable costs, average total cost, and marginal cost[4] .

Fixed costs are those payments which must be made regardless of the amount of production. For example, leased lines must be paid whether or not messages traverse the line. *Variable costs* are payments to variable factors of production. As the quantity of production increases, variable costs will also increase. Paper, used for reproduction of messages, is a variable cost. *Total cost* is fixed costs plus variable costs. The *average total cost* is the total cost divided by the quantity of production. Finally, *marginal cost* is the change in total cost (fixed or variable) per unit change in output. Marginal cost is the cost to send one more message. Figure 14 on page 26 illustrates the typical relationship between average total cost (ATC) and marginal costs (MC). [Ref. 2: p.271-276]

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4 Marginal cost is represented in supply. Used in the context of one firm, the term marginal cost vice supply is used.

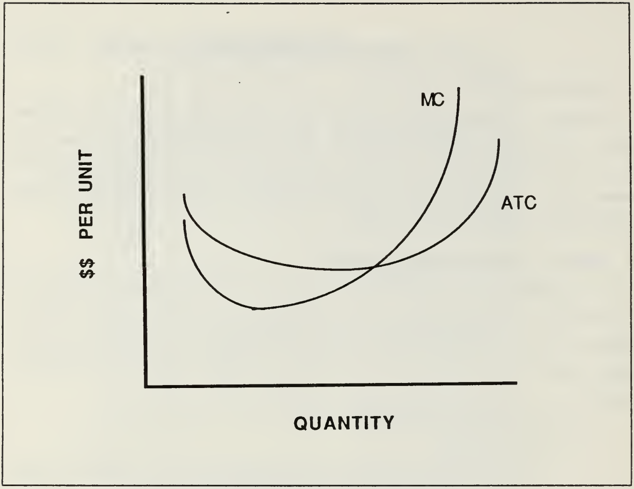

Figure 14. Average and Marginal Cost Curves (representative)

b. Marginal Cost Pricing

Marginal cost pricing, considered a cornerstone of economic efficiency is based on marginal cost [Ref. 15: pp. 13-14]. As illustrated in Figure 15 on page 27, the price *Pmc*, is the marginal cost at the quantity demanded *Qmc*. Marginal cost rates provide the consumer a rational relationship to the actual cost of the product. The supplier of the good should be indifferent to the quantity consumed, because the price received covers the marginal cost to produce the good [Ref. 16: p. 66]. In situations of decreasing costs, as illustrated in Figure 16 on page 28, suppliers realize a loss if marginal cost pricing is used. The marginal cost price *Pmc* per unit is lower than the average total cost *Cmc* incurred per unit.

Marginal cost pricing is difficult to apply when the commodity is supplied within a capacity constraint [Ref. 17: p. 14]. Capacity, as shown in Figure 17 on page

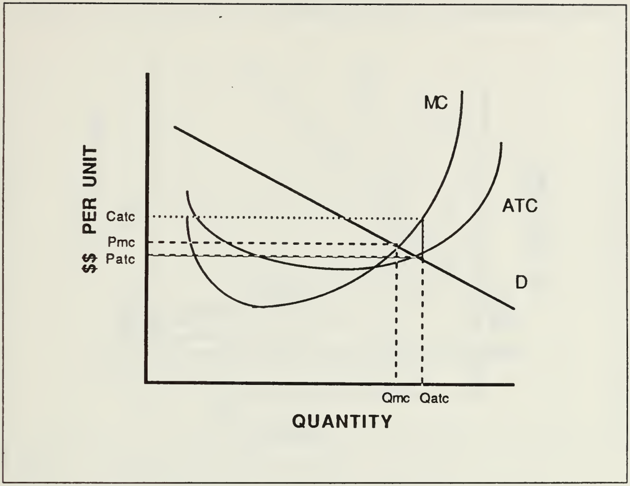

Figure 15. Marginal and Average Total Cost Pricing (representative)

29, is determined by the ability to give service within a time period. Capacity is exceeded when the customers do not receive service within the time allotted. For instance, capacity, at a restaurant, could be considered to seat and serve diners within 30 minutes. Capacity is exceeded if customers must wait longer than 30 minutes. Customers can be served in excess of capacity. If the quantity demanded exceeds capacity, to maximize efficiency those with the highest marginal benefits must be served first. Thus, the marginal cost at capacity, ***Pc***, must be used vice the normal marginal cost to equate demand and supply when capacity is reached.

c. Average Total Cost Pricing

In average cost pricing, price equals the average cost of the good or service at the quantity demanded. In Figure 15, the price ***Patc***, is the average total cost at quantity demanded ***Qatc***. The consumer, as in marginal cost pricing, is provided with a

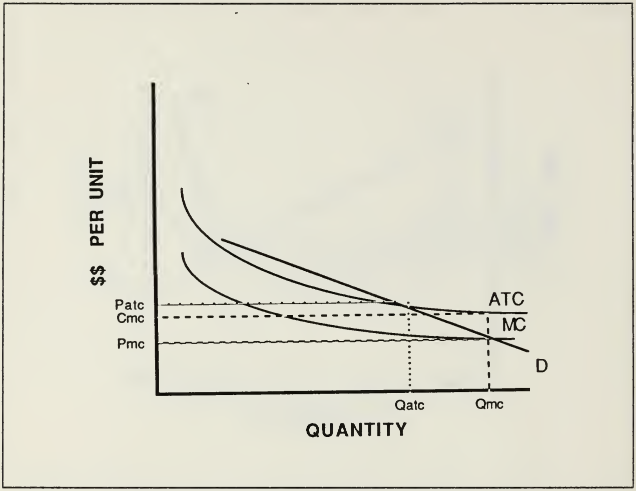

Figure 16. Marginal and Average Total Cost Pricing (decreasing costs)

rational relationship of the cost of the good. However, average total cost pricing does not provide incentives for suppliers to maximize efficiency. Suppliers recover all costs, including underutilized fixed costs.

Average total cost pricing is less efficient than marginal cost pricing, because the marginal cost does not equal the marginal benefit. As the quantity demanded increases, with average total cost pricing (*Qmc* to *Qatc*), the marginal cost also increases, (*Pmc* to *Catc*). The marginal cost *Catc*, may exceed marginal benefit *Patc* in average total cost pricing as shown in Figure 15 on page 27. The resources to produce the additional quantity demanded, could have been used more efficiently in a situation where marginal benefit exceeded marginal cost.

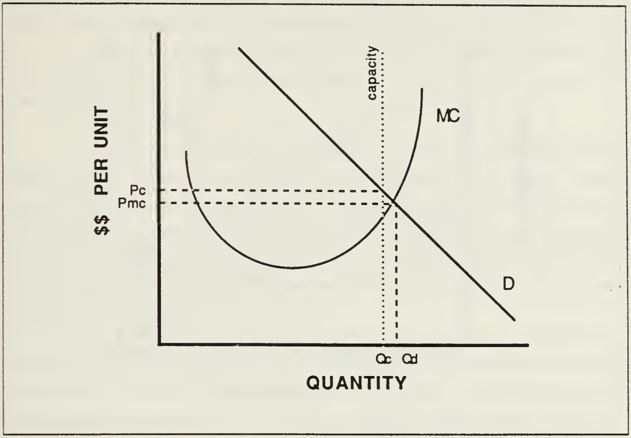

Figure 17. Marginal Cost Pricing at Capacity

In situations of decreasing costs (see Figure 16) suppliers are able to recover all costs. However, efficiency is not maximized. The marginal cost of producing the quantity demanded in average total cost pricing, ***Patc***, is less than the required price.

2. Demand-based Pricing Mechanisms

Demand-based pricing mechanisms address shifts, or fluctuations, in *demand*. Shifts which are predictable (i.e., end of the day or end of the month) use peak load pricing. Random fluctuations are addressed with priority pricing.

a. *Peak Load Pricing*

Unlike the cost-based pricing mechanisms, peak load pricing addresses the quantity demanded and the supply available within a particular time period. [Ref. 17: p.20] Peak load is the highest demand placed on a system during a period of time. If system capacity is based on the peak load, off-peak hours imply lesser demand and an underutilized capacity. If system capacity is set to satisfy requirements at off-peak periods, requirements will not be satisfied at peak periods.

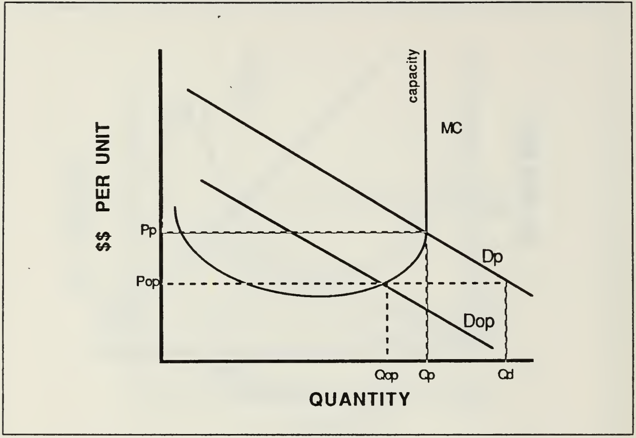

Figure 18. Peak Load Pricing

Peak load pricing, in essence, assigns different peak and off-peak prices to equate *demand* and *supply* in both periods of time; and attempts to shift some of the use from peak to off-peak periods stabilizing demand over time. In Figure 18 on page 30, ***Dp*** and ***Dop*** illustrate peak load and off-peak load demand, respectively. The peak load price, ***Pp***, equals the marginal cost at the quantity demanded, ***Qp***, at peak demand. The off-peak price, ***Pop***, equals the marginal cost at the quantity demanded, ***Qop***, at the off-peak demand. The peak load price is greater than off-peak price because marginal costs typically increase as capacity is reached.[5] If only one price was assigned for both peak and off-peak periods, efficiency would not be maximized. For instance, if the off-peak price, ***Pop***, was the sole priced used, during peak demand, ***Dp***, excess demand exists, and marginal cost (infinite) exceed marginal benefit, ***Pop***. If the peak price ***Pp***

[5] Several peak load pricing models; such as those of Boiteux, Steiner, Williamson and Buchana; attempt to formulate a price policy which leads to optimal amount of physical capacity and is consistent with marginal social cost. Details on these models are available in [Refs. 15, 16 and 17].

was the sole price used, during off-peak demand, ***D***, a surplus exists, with underutilization of resources. Similar arguments can be made for any single price.

Peak load pricing discourages use in peak time. Ideally, consumers will spread demand evenly over time, allowing requirements to be satisfied in all periods with a lower system capacity.

b. Priority Pricing

Priority pricing addresses consumption of a commodity when peak demand occurs randomly over time. Under a priority pricing scheme, users are offered a choice of prices. When demand exceeds supply, users paying higher prices receive priority over users paying lower prices. Thus, priority pricing provides a means to distinguish consumers with high marginal benefits from those with a lower marginal benefits. When system capacity is reached, efficiency can be maximized because the consumers with higher marginal benefits can be served first.

As illustrated in Figure 19 on page 32, system capacity is established to meet the quantity demanded at peak load times ***Qp***. If demand fluctuates from peak demand, ***Dp***, to a demand which exceeds system capacity, ***Dex***, the consumers with the highest marginal benefits can be served first. A priority pricing mechanism identifies, by a pre-negotiated contract, which consumers should be served first in an effort to maximize benefits. Electrical utilities who employ priority pricing give rebates to curtail service, to a pre-specified level, during periods where demand exceeds capacity. Customers allowing interruptible service are assumed to have lower marginal benefits. Those with the highest marginal benefits receive service first; maximizing efficiency. [Ref. 15: p. 188]

Ideally, priority pricing identifies consumers with high marginal benefits (maximizing total benefits) increasing system efficiency by ensuring that high value consumers are served before lower valued consumers with a lower system capacity.

3. Congestion Based Pricing Mechanisms

a. Marginal delay cost

Marginal delay cost pricing is a dynamic method of setting prices. It provides a means to capture the otherwise unperceived effect of congestion. A basis for marginal delay cost pricing is time. Delay is assigned a monetary amount, on a per unit basis (i.e., second); *$V = per unit time delay*. Marginal delay cost curves may be computed for the delay, typically unperceived by the consumer, incurred because of congestion.

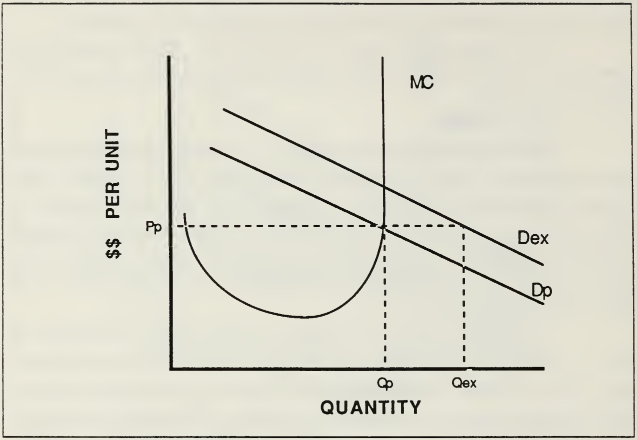

Figure 19. Priority Pricing

Dolan [Ref. 18: pp. 18-21] explains and shows the relationship of *perceived delay cost (PDC), marginal delay cost to the system (SMC),* and *marginal delay cost to others (MCO)* Figure 20 on page 33 illustrates the relationship of PDC, SMC and MCO for various utilization rates.[6] Perceived delay cost (PDC) is the delay cost to an individual, for remaining in line for service. Mathematically, it is the expected average time waiting in queue. Marginal delay cost to the system (SMC) is the total effect of delay cost to the system. It is the derivative of the expected aggregate waiting time of users. Marginal delay cost to others (MCO) is the delay cost to all others in the line, incurred from the additional person waiting for service. Marginal delay cost to others is the difference of marginal delay cost to the system and perceived delay

6 Illustrated is a M/M/1 situation, single server with a Poisson arrival rate, and exponential service. Although not identical to the NTS queue (preemptive priority) with a Poisson arrival rate, and exponential service, it illustrates the effects of system delay.

cost (MCO = SMC - PDC). Normally, the MCO is unrecognized by the consumer. This results in inefficiency at equilibrium, as discussed in Chapter Two, on page 8.

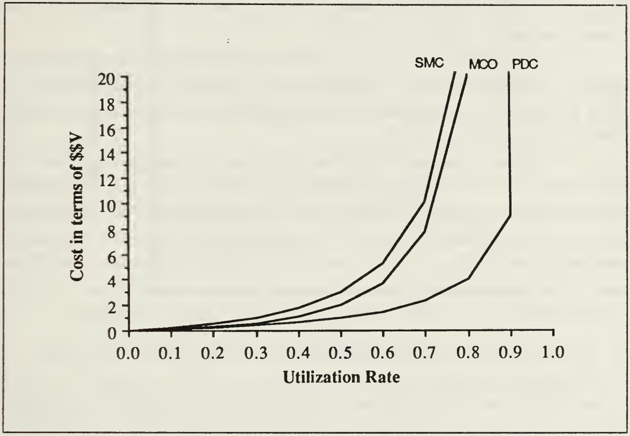

Figure 20. Marginal and Perceived Delay Cost Schedules

In terms of record communications, PDC is the user's perception of the length of time Message A should normally be in queue awaiting transmission. MCO is the effect to all other messages, due to Message A being transmitted. SMC is the total effect of delay because of all messages transmitted. For instance, suppose a message system normally had 20 messages in queue, each message was 100 characters long, and the speed of transmission was ten characters per second. An instantaneous look at this message system would reveal the following relationships between PDC, MCO and SMC. If Message A was the seventh message in queue the PDC is 70 seconds, as that is the length of time waiting in queue before transmission.[7] The MCO of Message A is the cost of delay to the 13 messages waiting in queue *after* Message A. Those 13 messages (and

7 If users drop their messages off at a message center and leave (as typically happens) it is possible that the PDC is less than proposed by Dolan because users do not experience the time waiting in queue.

any additional message that arrives) will be delayed ten seconds for transmission of Message A. Assuming no other messages arrive, the MCO is 130 seconds; which is part of the total cost of transmitting Message A. Thus, the SMC for Message A is 200 seconds, the sum of MCO and PDC.

The amount of delay is dependent on the utilization rate (mean arrival rate divided by the mean service rate). Figure 20 on page 33 shows the dramatic impact, in terms of time delay, of high utilization rates. As the utilization increases, the delay increases at an increasing rate.

Figure 21 on page 35 [Ref. 18: p. 22], illustrates the perceived delay cost (PDC) for a given utilization rate, and the resulting marginal delay cost to the system (SMC). Dolan [Ref. 18: pp. 20-24] continues to explain that marginal delay cost pricing, sets price ***Ps***, at the quantity demanded at the system cost ***Qs***, rather than at the quantity demanded at the individual cost ***Qi***, to maximize efficiency. If price was set at ***Pi***, the quantity demanded ***Qi***, would cause an increase in system marginal delay to ***Ci*** The marginal cost ***Ci***, is greater than the marginal benefit ***Pi***, decreasing efficiency.

C. PRICING MECHANISMS APPLIED TO RECORD COMMUNICATIONS

Assuming technology and mind-set permits a pricing strategy for record communications, each pricing mechanism should elicit a different behavioral response from users of record communications. As discussed in Chapter Two, congestion and delay is dependent on the number of messages (including number of addees), the length of a message, the rate of arrival (volume in a time period), and its assigned precedence. Thus, to be an effective demand management tool, pricing mechanisms must give incentive to the user to minimize the:

- Number of messages sent (including number of addees);
- Length of a message;
- Rate of arrival (number sent in a time period); and
- Precedence level assigned.

1. Cost Based Pricing

Marginal and average total cost pricing could be applied on either a per character[8] , or a per message basis. Both mechanisms would receive similar responses from the user, although greater efficiency would be realized with marginal cost pricing.

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[8] The basis could be taken down to a byte or bit level. Character will be used in reference to a character or smaller basis.

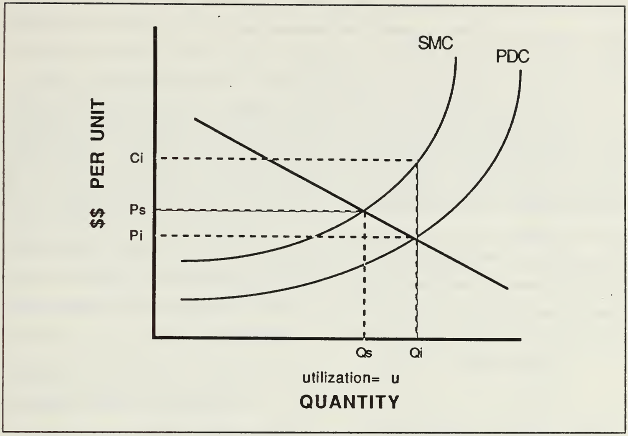

Figure 21. Marginal Delay Cost Pricing

If marginal or average total cost pricing were employed on a per message basis, users would tend to send fewer messages. However, users may put more information into a particular message, as opposed to sending more messages, which may increase the length of a message. The rate of arrival and precedence assignment would not be effected by the cost-based pricing mechanisms. Efficiency should improve because the quantity demanded is reduced moving the system toward the point where marginal cost and marginal benefit are equated. (Marginal cost and marginal benefit are equal in marginal cost pricing.)

2. Demand Based Pricing

Employment of peak load pricing would result in a increase of price during periods with higher demand (i.e., end of the day, end of the month). The rate could be based on a per message or a per character basis. Indirectly, because the basis of charge is the marginal cost, the number and/or length of the messages would be effected like marginal or average total cost pricing. Because a higher price would be imposed during peak hours, users would send only messages with higher marginal benefits. Thus, rate of arrival to the communication center, during peak hours, should decrease, and perhaps spread evenly over time. Precedence assignment would not be effected. Peak load pricing allows greater efficiency, as marginal costs and marginal benefits are matched.

A priority rate could be applied, corresponding to the assigned precedence level of a message. This implies increasing marginal benefits with increasing precedence levels. A flash message would have a higher fee than a routine message. Additionally, priority pricing could be applied to messages within each precedence level (i.e., all routine messages). A rebate could be given to the users allowing other messages within the same precedence level to be processed first. Indirectly, because the basis of charge is marginal cost, the number and/or the length of the message would be effected like marginal or average total cost pricing. Rate of arrival would not be effected. Users would assign the minimum precedence level. Priority pricing allows the messages with higher marginal benefits to be processed first, increasing efficiency.

3. Congestion Based Pricing

Marginal delay cost pricing provides a means to capture the otherwise unperceived effect of congestion. A utilization rate to support the speed of service objective with the corresponding perceived and marginal cost schedules would be computed based on queuing theory. The unit used for the per unit delay cost could be a character or a message. This would have the same effect on number or length of messages as the cost-based pricing mechanisms. The arrival rate and precedence assignment would not be effected. Marginal delay cost pricing allows the "true" marginal cost of sending messages, in terms of congestion, to be used which will increase efficiency.

4. Price Mechanism Summary

Each pricing mechanism accomplishes different objectives. The cost-based pricing mechanisms capture all tangible costs associated with the providing record communications. The demand-based pricing mechanisms are able to deal with fluctuations in demand. Congestion-based pricing mechanisms capture the normally unperceived cost of delay which is associated with record communications. Used simultaneously, a price can be assigned which would capture all costs (tangible and delay), and be able to deal with fluctuations in demand. Figure 22 on page 38 shows how cost-based, demand-based, and congestion-based pricing mechanisms could be used simultaneously. The costs include: marginal (operating) costs, ***MC***, perceived delay cost, ***PDC***, and marginal delay cost to the system, ***SMC***. Typical demand and a fluctuation in demand are represented by ***D*** and ***D1***. Shown is the change in quantity demanded as cost-based, and congestion-based pricing mechanisms are employed. For demand ***D***, with price at zero quantity demanded is ***Q****. Marginal cost pricing dictates a quantity demanded, ***Qmc***, at the corresponding price, ***Pmc***. The effect of congestion-based pricing is illustrated as price increases and quantity demanded decreases with inclusion of perceived delay cost (***Pp*** and ***Qp***) and increased again when the marginal delay to others is added to get the marginal delay cost to the system (***P*** and ***Q***). Similarly, price and quantity demanded may be derived when demand fluctuates from ***D*** to ***Dp***.

The appropriate pricing mechanism and/or combinations of pricing mechanisms depend on the characteristics of supply and demand. For instance, if the marginal cost of operating the record communications system was insignificant, cost-based pricing mechanisms would not be appropriate. If congestion was not a problem, congestion-based pricing is unnecessary.

D. PRICE IMPLEMENTATION

To implement pricing, characteristics of supply, demand, and congestion must be analyzed. The marginal cost of operating the record communication system, for each transmission medium and system must be calculated. Characteristics of demand, such as predictable peak and off-peak periods, must be determined. In terms of congestion, the utilization rate (based on queuing theory) to give the optimum delivery rates must be calculated. Also, a per unit delay dollar amount must be determined.

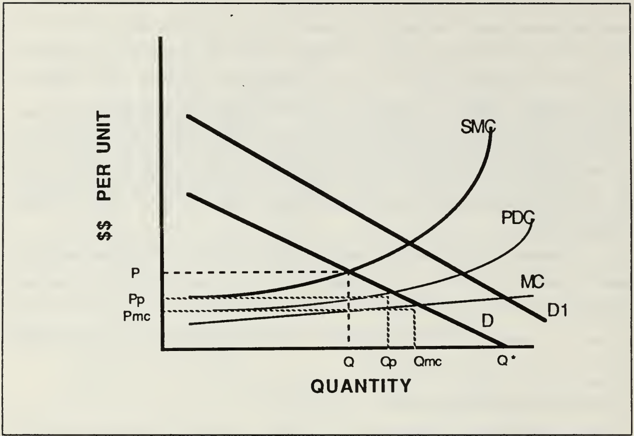

Figure 22. Simultaneous Pricing Mechanisms

V. COST ESTIMATION

A. INTRODUCTION

One step in determining a justifiable cost-based or demand-based pricing mechanism is determining the applicable costs. This chapter describes a basic framework for identifying operating costs within the NTS, and a cost estimation model.

B. COST-BASED AND DEMAND-BASED PRICING MECHANISMS

To develop a pricing structure to achieve efficiency of the NTS, the marginal cost (by message or character) of record communications must be determined. It is the basis for both cost-based and demand-based pricing mechanisms. Cost-based pricing mechanisms require identification of costs on the service life of the system; demand-based pricing mechanisms require identification of costs on a period (i.e., daily) basis that equates to capacity and demand within that period.

Identification and allocation of the costs associated with record communications are complex because:

- Marginal costs are dependent on the transmission mode;
- Multiple facilities, each with varying costs, are used to accomplish record communications; and
- Equipment has both joint and dedicated use.

For example, various transmission modes and systems employed appear to have different marginal costs. A satellite communications system requires a huge capital investment to establish the link and a seemingly small cost in manpower to operate the system. Hence, it appears to have very low marginal cost. On the other hand, a high frequency full period termination may record a greater cost in manpower producing a higher marginal cost. Numerous facilities, located world-wide, are necessary to accomplish the tasks of message acceptance, transmission and delivery. Some facilities are geared to provide a specific type of acceptance (i.e., Naval Telecommunications Centers) or a specific type of transmission (i.e., transmitter facility). These facilities may not only have different types of costs, but also a different range of costs. Finally, providing record communications is not a simple factor process. Messages are not tied to specific pieces of equipment. All messages may use a particular system at some point in their route, but the message will invariably use several other pieces of equipment independently. Due to all the differences in transmission modes/systems, the myriad facilities, and equipment, a method is necessary to separate and divide recorded costs appropriately in order for the marginal cost of record communications to be determined.

C. BASIC FRAMEWORK

The complexity of the Naval Telecommunications System architecture and the complexity of the associated costs create an infinite maze of information to determine the cost of record communications. A "black box" approach provides a basic framework to start the cost estimation process.

Viewed as a "black box", the NTS has inputs from and outputs to the users. Within the "black box," a message may go through several electronic transformations and be transmitted to several geographic areas. Regardless of how and where the message is processed, funds are expended and can be traced to an individual command. All commands within the black box, in aggregate, may provide the costs associated with record communications.

Within the black box, numerous individual commands in the NTS can be depicted (i.e., Naval Communications Stations and Naval Telecommunications Centers). Each command may have responsibility for one or more steps in providing record communications. (The steps are accept, transmit and deliver.) The basic framework allows identification of these steps, permitting segregation of the users and providers of record communications. The basic framework for cost estimation is illustrated in Figure 23 on page 41.

D. COST ESTIMATION MODEL

Using the basic framework, a cost model can be completed for each command within the NTS. Data regarding costs must be collected and allocated.

1. Data

Any item resulting in a transfer of funds related directly or indirectly to record communications must be identified. This includes such items as: leases, contracts, utilities, manpower, consumables, and equipment. Additional data about each item must also be recorded such as cost, acquisition date, and service life, to allow appropriate allocation and accounting.

2. Allocation Groups

The model provides for both cost and processing step categories. Each item's cost is allocated against both groups. The appropriate allocation of each item depends

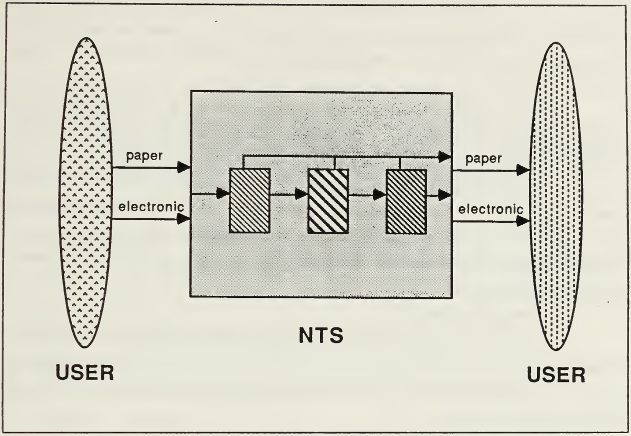

Figure 23. Basic Framework for Cost Estimation

on the objective of the cost estimation (i.e., price, cost benefit analysis), which goes beyond the scope of this thesis.

a. Cost Allocation

Four cost allocation categories based on telephone literature [Ref. 19: p. 70 and 20: p. 192] are used. They allow identification of costs that are incurred universally to messages, and costs that are incurred because of the particular mode/system of transmission. Ultimately these categories will allow identification of average total costs and marginal cost of sending messages via a particular system.

(1) Connectivity Cost. Because the NTS provides record communications to a variety of users, multiple connectivity methods are used. The equipment and costs directly attributable to its operation and maintenance are connectivity costs. These costs are typically fixed. Each connectivity method (i.e., satellite, high frequency, and landline) must be identified, because each will produce a different cost.

(2) Capacity. Typically fixed costs, the costs of providing service regardless of connectivity means and demands placed on the system, are capacity costs. The acquisition and maintenance cost of the NAVCOMPARS or LDMX, systems used by all messages (non-tactical), is an example of a capacity cost.

(3) Traffic. Costs incurred because a message is processed, irrespective of mode, system or congestion, is a traffic cost. These costs are the marginal cost of sending a message. Items include electrical power and operators' salaries.

(4) Overhead. Costs associated with record communication that are not directly chargeable to the other categories, are overhead. These costs are typically fixed and are incurred because of administration and management. The salary of division officers, department heads, etc. and cost incurred because of research and development, are examples of overhead.

b. Processing Step

The NTS accepts, transmits, and delivers messages; however, an individual command within the NTS may be involved with only one step throughout the total service. This requires annotation, for each item, of what step (accept, transmission, and delivery) the item was used.

E. DATA COLLECTION

The process of collecting and allocating cost data will be an enormous task. The data necessary to complete a cost estimation is not located in a central repository. For instance, acquisition is a centralized process, whereas operating and supporting costs are typically maintained by individual commands. Allocation of the data to the appropriate cost allocation group (connectivity, capacity, traffic, overhead) will be open to individual interpretation. Additionally, questions will arise as to the detail and applicability of data (i.e., costs in support of the Joint Chiefs of Staff communication).

VI. FINDINGS

A. INTRODUCTION

The objective of this thesis was to examine alternative pricing mechanisms to manage the demand and increase the efficiency of the NTS. It is the start of a very difficult process of developing a pricing strategy for record communications.

B. FINDINGS

1. Targets for Demand Management

The NTS is a congestion-based system with three conceivable points of delay: entry into the NTS, waiting transmission, and delivery. To effectively manage congestion and delay, the following items must be targeted:

- number of messages (including number of addees);
- length of messages;
- arrival rate (volume in a time period); and
- precedence assignment.

2. Current Demand Management

An excess demand for record communications should normally be expected because the price is set at zero and a capacity limitation exists.

Currently, demand for record communications is managed by administrative procedures. The procedures are effective with regard to decreasing the volume of messages. However, if the length, arrival rate, and precedence assignment of messages are not minimized the speed of service objectives will continue to be exceeded, ceteris paribus.

3. Speed of Delivery Data

Program SRPA, *Traffic Analysis Reports,* provides concrete reporting of delivery speed. This information, however, is incomplete and somewhat misleading as to the actual speed with which an individual message is delivered--writer to reader. The reports are based on entry and exit from a particular NAVCOMPARS, which does not include the delay waiting to enter the NAVCOMPARS nor delay to travel through other necessary systems.

Handling time, which may be considered speed of delivery, is displayed on summary reports as an average. Averages, however, do not reveal the number of messages which exceed the speed of service objective, nor do they give an indication of what the actual handling time is.

4. Pricing

Pricing, as a demand management tool, should increase the efficiency of the NTS. The appropriate pricing mechanism is dependent upon the characteristics of supply and demand. Cost-based and congestion-based pricing mechanisms capture the cost of operation and delay, respectively. Demand-based pricing mechanisms are able to maximize efficiency when fluctuations in demand occur.

C. AREAS FOR FURTHER STUDY

This thesis provides a foundation for pricing as a demand management tool. To implement pricing, an actual dollar price must be determined. This requires an analysis of supply, demand, and congestion. A dollar amount for a per unit delay cost must be ascertained. If the characteristics of operations costs, demand, or congestion are significant, the corresponding pricing mechanism must be used.

Implementation of a user-paid record communications system raises numerous questions.

- How would users be allocated money to pay for a service that was previously free?
- How would the appropriate amount of money each command would receive for record communications be determined?
- Who would pay for a message--the sender or the receiver?
- Would the accounting system, necessary to account for all users, be cost prohibitive?
- If a command exceeded their budget, would the message be sent? Who would pay for it?
- Would vital information be lost because commands elected not to send a message?
- Would pricing as a demand management tool for record communications work?

The analysis of supply, demand and congestion, along with these questions, each a separate topic of analysis, must be used to determine if a user-paid system would benefit the U.S. Navy.

LIST OF REFERENCES

1. Mings, Turley, *The Study of Economics; Principles, Concepts and Applications,* 3d ed., The Dushkin Publishing Group, Inc., 1987.

2. Maurice, S. Charles and Smithson, Charles W., *Managerial Economics,* 3d ed., Irwin, Inc., 1988.

3. *Telecommunications Users Manual,* Naval Telecommunications Procedure, Volume 3 (G), February 1987.

4. Babb, Robin M., *The Naval Telecommunications System: A Command and Staff Manual,* Master's Thesis, Naval Postgraduate School, Monterey, CA, March 1987.

5. Chief of Naval Operations Instruction 5450.18E, *Mission and Functions of Commander, Naval Telecommunications Command,* 28 March 1985.

6. Markland, Robert E. and Sweigart, James R., *Quantitative Methods: Applications to Managerial Decision Making,* John Wiley & Sons, Inc., 1987.

7. Psillas, Christopher F., *An Economic Evaluation Of Marine Corps UHF Ground Terminal Satellite Communications Acquisition,* Master's Thesis, Naval Postgraduate School, Monterey, CA, March 1989.

8. CNO Washington DC Naval Message, NAVOP 142/85, Subject: Mailed Message Pilot Program, 251608Z Nov 85.

9. CNO Washington DC Naval Message, NAVOP 069/86, Subject: Navy Mailed Message Program (NAVGRAMS), 262339Z Jun 86.

10. CNO Washington DC Naval Message, NAVOP 116/86, Subject: Communications Discipline 121728Z Nov 86.

11. Department of the Navy, Office of the Chief of Naval Operations, OPNAVNOTE 2300, Ser 09/6U301489, Subject: Communications Discipline, 11 Dec 1986.

12. CNO Washington DC Naval Message, NAVOP 013/89, Subject: Communications Discipline, 171849Z Feb 89.

13. Interview between M.H. "Buzz" Hoever, Captain, USN, Naval Postgraduate School, Monterey, CA, and the author, 7 February 1989.

14. Naval Communications Area Master Station, Atlantic, Norfolk, VA, *Program System Reporting Processing Analysis (SRPA), Traffic Analysis Reports,* Radio Day 23-39, 1989.

15. Crew, Michael A. and Kleindorfer, Paul R., *The Economics of Public Utility Regulation,* The MIT Press 1986.

16. Sichel, W. and others, *Applications of Economic Principles in Public Utility Industries,* pp. 51-72, The University of Michigan, 1981.

17. Greene, Robert L., *Welfare Economics and Peak Load Pricing,* University of Florida Press, 1970.

18. Dolan, Robert J., *Priority Pricing Models for Congested Systems,* Doctoral Dissertation, The University of Rochester, Rochester, NY, 1976.

19. Hazlewood, A., "Optimum Pricing as Applied to Telephone Service," *Review of Economic Studies,* v. 18, pp. 67-78, 1950-1951.

20. Littlechild, S.C., "Peak Load Pricing of Telephone Calls" *The Bell Journal of Economics and Management Science,* v.1, pp.191-210, Autumn 1970.

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